(12) UK Patent Application (19) GB (11) 2 162 454 A

(43) Application published 5 Feb 1986

(21) Application No 8419654

(22) Date of filing 1 Aug 1984

(71) Applicant
Dowty Rotol Limited (United Kingdom),
Cheltenham Road, Gloucester

(72) Inventor
Brian James Daws

(74) Agent and/or Address for Service
J L Curtis,
Dowty Group Services Limited, Patents Department,
Arle Court, Cheltenham, Glos GL51 0TP

(51) INT CL⁴
B23H 9/00

(52) Domestic classification
B3V 101 102 EQ
B3A 73
U1S 2016 B3V

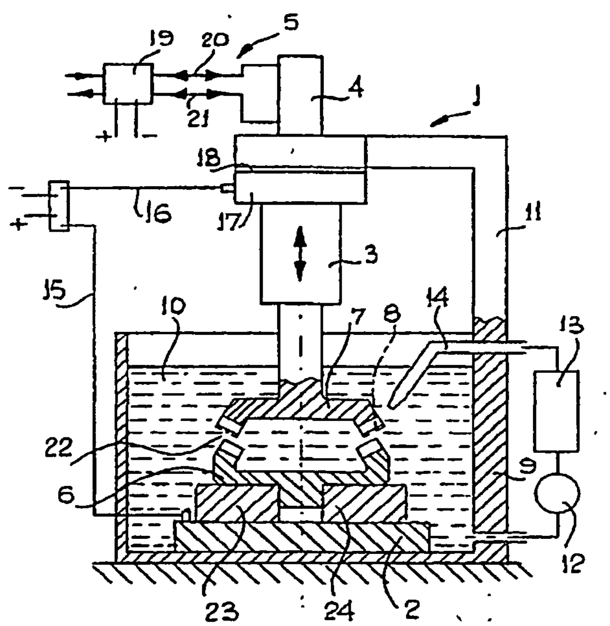
(56) Documents cited
GB A 2096518 GB 1505065 GB 0974338
GB A 2072562 GB 1032799 GB 0919010

(58) Field of search
B3V

(54) Method of manufacturing internally-toothed bevel gear and apparatus therefor

(57) The method comprises producing an internally-bevelled gear blank 6 which forms a first electrode, and a second electrode 7 of externally-bevelled formation so shaped as, by the method, to be capable of providing the first electrode with an internally-bevel-toothed formation intended to mesh, at least approximately, with an externally-toothed bevel pinion subsequently required to co-operate therewith.

The two electrodes are mounted on a machine 1 and the second electrode is advanced into close proximity to the first electrode, electrical current then being conducted across the electrodes to cause electric discharge or electro-chemical erosion of the first electrode. A constant gap 22 is maintained between the electrodes until such erosion of the first electrode has occurred that it reaches an internally-toothed shape which is substantially the mirror image of the externally-toothed shape of the second electrode.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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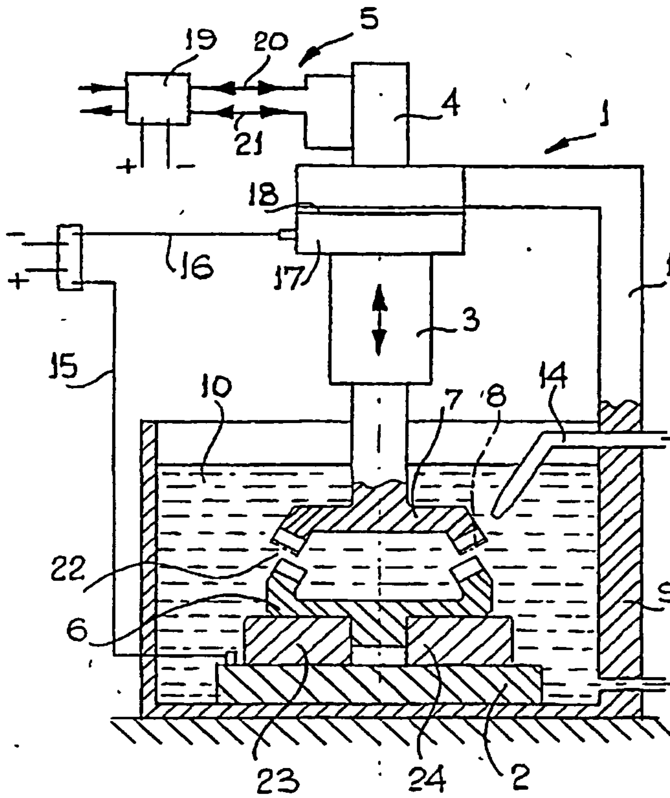

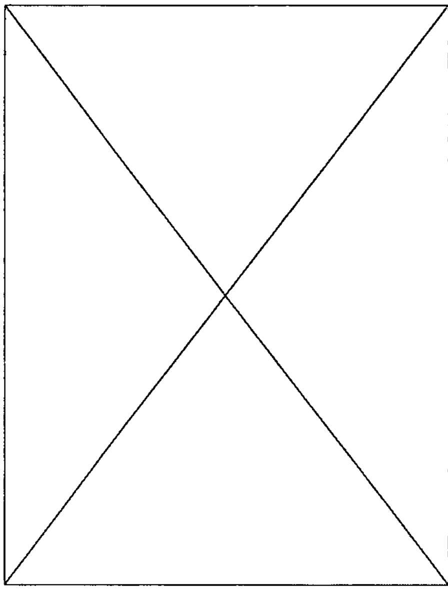

internally-

ing said first electrode with an internally-bevel-toothed formation intended to have a precision meshing fit with respect to said

nally-bevelled shape and from which it is intended that the finished gear is produced, is preformed in high tensile carburising steel in readiness for mounting on work-table 2. This blank, being electrically-conductive, forms a first electrode when so mounted on the work-table.

A second electrode 7 and a third electode 8, both of copper, are now produced in suitable manner in readiness for separately mounting in holder 3. These electrodes each have an externally-bevel-toothed formation so shaped as to be capable, by the method of this invention, of providing first electrode 6 with an internally-bevel-toothed formation intended to mesh with an externally-toothed production bevel pinion (not shown) subsequently required to cooperate therewith in service. It is also intended that the formation produced by electrode 7 will be so dimensioned as to be capable of approximate meshing with the pinion, while the formation produced by electrode 8 will be so dimensioned as to be capable of having a precision meshing relationship with respect to the pinion. Thus, the electrode 7 forms a "coarse" electrode and the electrode 8 forms a "fine" electrode and, as indicated in somewhat exaggerated manner in the drawing by the dotted lines, the toothed profiles of electrode 8 are very slightly larger than those of electrode 7.

The machine 1 includes a reservoir 9 for dielectric fluid 10. The holder 3 and the hydraulic ram 4 are supported above the reservoir and work-table by member 11 which is itself fast with the wall of the reservoir. A pump 12 is provided externally of the reservoir adjacent the base thereof and dielectric fluid pumped from the reservoir is passed through a filter 13 and then through pipe 14 back into the reservoir.

A conductor 15 taken from the positive side of a source of electrical current connects with the work-table 2 and a conductor 16 is taken from the portion 17 of holder 3, which is electrically insulated at 18 from ram 4, to negative.

When the gear blank 6 is fitted to the work-table 2 it forms a first electrode for machine 1. On fitment of the second electrode 7 to holder 3 the two electrodes are coaxially disposed.

Before electrical discharge machining of the gear blank 6, i.e. of the first electrode, can commence the servo mechanism 5 is brought into operation. Accordingly electro-hydraulic servo valve 19, which forms part of servo mechanism 5, is operated so that liquid under pressure from a suitable source (not shown) is directed through pipe 20 to the upper side of ram 4 while the lower side of the ram is placed in communication with reservoir (also not shown) by way of pipe 21. Ram 4 thus lowers holder 3 so that second electrode 7 is positioned in close proximity to first electrode 6 in which a small predetermined gap 22, in this embodiment .006", is provided between the two electrodes. This gap is shown rather exaggerated in the drawing.

Electrical current is now passed through the conductor 15 to work-table 2 and thus to electrode 6 which is suitably clamped on the work-table through the intermediary of mounting blocks 23, 24. This current passes across the gap 22 between electrodes 6 and 7 and then through holder 3 and conductor 16 to negative. As current passes across gap 22 spark erosion of the steel of the gear blank 6 occurs so that the internally-toothed profiles of the gear take shape. While this shaping progressively takes place the servo mechanism 5 is operable automatically in suitable manner to maintain gap 22 substantially constant. Simultaneously, dielectric fluid 10 is flushed through the gap from pipe 14, this fluid serving as a coolant and as a spark conductor. It also serves as a vehicle for flushing small particles or chips of steel removed from the blank as the internally-toothed bevel gear is formed. Also simultaneously, pump 12 is operating to pump particle-containing dielectric fluid out from reservoir 9 and through filter 13, whereafter clean fluid passes through pipe 14 back into the reservoir for flushing gap 22. Suitable dielectric fluids are silicone oils, deionized water and hydrocarbon oil of suitable viscosity.

When the electrical discharge machining operation has advanced sufficiently for blank 6 to have reached an internally-toothed condition in which it is the mirror image of the "coarse" second electrode 7, the process is stopped and ram 4 is operated to raise electrode 7 away from blank 6 for removal from holder 3. Electrode 7 is replaced in holder 3 by the "fine" third electrode 8 indicated by dotted lines in the drawing.

The servo mechanism 5 is then re-operated to lower the third electrode into close proximity to blank 6 in which a gap of .0015" is established between them.

Electrical current is now passed through conductor 15 to work-table 2 and across electrodes 6, 8 so that further spark erosion of the gear-blank takes place to complete the shaping of the internally-bevelled tooth profiles of the gear. While this final shaping progressively takes place servo mechanism 5 is again operable to maintain gap 22 substantially constant. Also, simultaneously, dielectric fluid 10 is flushed through the gap from pipe 14, and pump 12 again pumps fluid from reservoir 9 through filter 13.

When this second stage of electrical discharge machining operation has advanced sufficiently for gear-blank 6 to have reached an internally-toothed condition in which it is the mirror image of the "fine" third electrode 8, the process is stopped and the internally-toothed bevel gear is removed from the ma-

chine.

By this second stage of machining operation only another .012" of material may have been removed from the blank in order to so form the gear.

Also during one or other or both of said electrical discharge machining operations a small amount of orbiting of the second and/or third electrodes may be suitable apparatus be caused to take place.

It will be understood that suitable heat treatment of the gear can be effected at any desired stage during the above manufacturing processes.

In this embodiment the first (coarse) stage of the process continues for approximately $1\frac{1}{2}$ hours, while the second (fine) stage continues for $\frac{1}{2}$ an hour. Thereafter the internally-toothed bevel gear is lapped by running a special externally-toothed bevel pinion in mesh therewith. This pinion is substantially identical to the production pinion subsequently required to mesh with the bevel gear and is coated with cubic boron nitride to a depth of .004" which acts as an abrasive. In the lapping process the pair of gears are set with correct assembled backlash and are run in opposite directions with predetermined torque applied thereto to achieve best surface finish. During lapping approximately .001" of material (the "re-cast" layer associated with electrical discharge machining) is removed from the flanks of the teeth of the internally-toothed bevel gear.

The internally-toothed bevel gear so formed can now be fitted in a gear box and arranged to mesh with the production bevel pinion.

In an alternative embodiment of the invention instead of the "coarse" stage of the gear-shaping operation being effected by an electrical discharge machining operation, it is effected by an electrochemical machining operation in which metal is removed by anodic dissolution in an electrolytic cell in which the workpiece is the anode and the tool is the cathode. Here an electrolyte, for example an aqueous solution of inorganic salts such as sodium chloride, potassium chloride, sodium nitrate or sodium chlorate, or again a sulphuric acid or a sodium hydroxide solution, is pumped through a suitable gap between the workpiece and the tool.

By the invention it is now possible to manufacture high precision internally-toothed bevel gears from a high grade material avoiding the practical difficulties of normal mechanical machining and thus producing such gears very economically, particularly such gears which are required to mesh with bevel pinions, the shafts of which are each set at an obtuse angle (for example of the order of 160°) to the rotational plane of the associated internally-toothed bevel gear, and such bevel pinions being of substantially smaller diameter at their externally-bevel-toothed formations than those of the second and third electrodes.

CLAIMS

1. A method of manufacturing an internally-toothed bevel gear comprising the steps of:– (a) producing a gear blank, of required internally-bevelled shape and of electrically-conductive material, which forms a first electrode, (b) producing a second electrode of externally-bevel-toothed formation, said formation being so shaped as, by said method, to be capable of providing said first electrode with an internally-bevel-toothed formation intended to mesh, at least approximately, with an externally-toothed bevel pinion subsequently required to co-operate therewith, (c) mounting said first electrode and said second electrode on a machine which is capable of effecting controlled erosion of said first electrode without imparting mechanical force thereon, (d) advancing the second electrode into close proximity to said first electrode, (e) conducting electrical current across said electrodes thereby to cause erosion of said first electrode, and, (f) maintaining a constant gap between said electrodes during continued supply of current across said electrodes until such erosion of said first electrode has occurred that it reaches an internally-toothd shape which is the mirror image of the externally-toothed shape of said second electrode, or substantially so.

2. A method as claimed in claim 1 and further comprising the steps of:– (a) producing a third electrode similar to said second electrode but having an externally-bevel-toothed formation so shaped as, by said method, to be capable of providing said first electrode with an internally-bevel-toothed formation intended to have a precision meshing fit with respect to said externally-toothed bevel pinion, (b) removing said second electrode from said machine and replacing it by said third electrode, (c) advancing said third electrode into close proximity to said first electrode, and (d) conducting electrical current across said first and third electrodes thereby to cause such further erosion of said first electrode that it reaches an internally-toothed shape which is the mirror image of the externally-toothed shape of said third electrode, or substantially so.

3. A method as claimed in either claim 1 or claim 2, wherein the step of eroding said first electrode by use of said second electrode is by electrical discharge machining.

4. A method as claimed in either claim 1 or claim 2, wherein the step of eroding said first electrode by use of said second electrode is by electro-chemical machining.

5. A method as claimed in claim 2, or as claimed in either claim 3 or claim 4 when dependent on claim 2, wherein the step of final erosion of said first electrode by use of said third electrode is by electrical discharge

machining.

6. Apparatus, suitable for manufacture of an internally-toothed bevel gear by the method as claimed in any one of the preceding claims, including a machine adapted for either electrical discharge machining or electrochemical machining having a work-table for supporting said first electrode, a holder upon which said second or third electrode can be mounted and a mechanism for advancing said second electrode or said third electrode into close proximity to said first electrode and for maintaining a constant gap between said electrodes during continued supply of current across said electrodes.

7. Apparatus as claimed in claim 6, wherein said blank or first electrode is of high tensile carburising or nitriding steel.

8. Apparatus as claimed in either claim 6 or claim 7, wherein said second and/or third electrodes are of copper.

9. A method of manufacturing an internally-toothed bevel gear substantially as hereinbefore described with reference to the accompanying drawing.

10. Apparatus, suitable for manufacture of an internally-toothed bevel gear, substantially as hereinbefore described with reference to the accompanying drawing.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1986, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.